Lab – 4
Vibration characteristics of a slender beam

Objective

(A) Observe a beam vibrating under resonance, and retrieve its fundamental frequencies

(B). Record acceleration and strain histories in a vibrating cantilever beam and evaluate its vibration characteristics by employing Fast Fourier Transform

Introduction

Free vibration occurs when a mechanical system is set in motion with an initial input and allowed to vibrate freely. The mechanical system vibrates with a combination of frequencies, out of which one or more may be dominated. If left unperturbed, the vibration damps down to motionlessness. Some of the examples of free vibration are, pulling a child back on a swing and letting it go, or hitting a tuning fork and letting it ring.

Forced vibration is observed when a time-varying disturbance (load, displacement or velocity) is applied to a mechanical system. The disturbance can be periodic with steady-state, transient or random input. The periodic input can further be divided into harmonic and non-harmonic disturbance. The importance of this mode rises in the engineering field. Machines, motors and other industrial applications, exhibits this mode of vibrations, which may cause a serious damage of the equipment. Washing machine shaking due to an imbalance, transportation vibration caused by an engine or uneven road, or the vibration of a building during an earthquake are some of the examples of forced vibration.

Following are the equipment used in laboratory to conduct the vibration experiment.

(a)


(b)


(c)


(d)

(a) Electrodynamic shaker
(b) Function generator
(c) Power amplifier
(d) Stroboscope

Specimen dimensions

Specimen dimensions are as shown in the figure below (Fig.3.1)

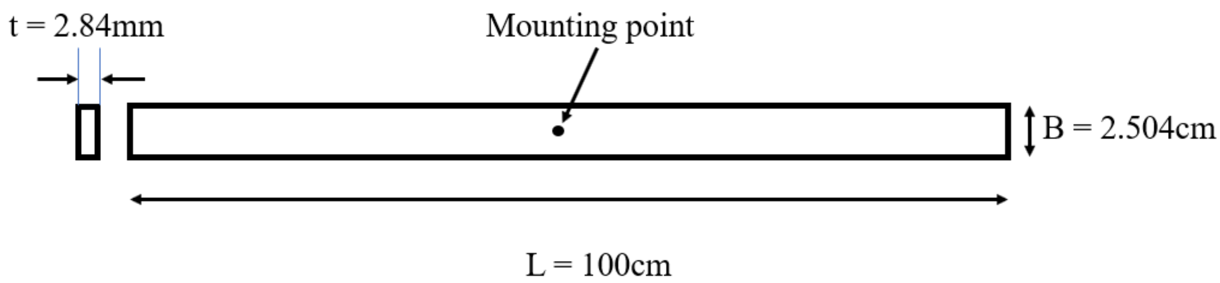
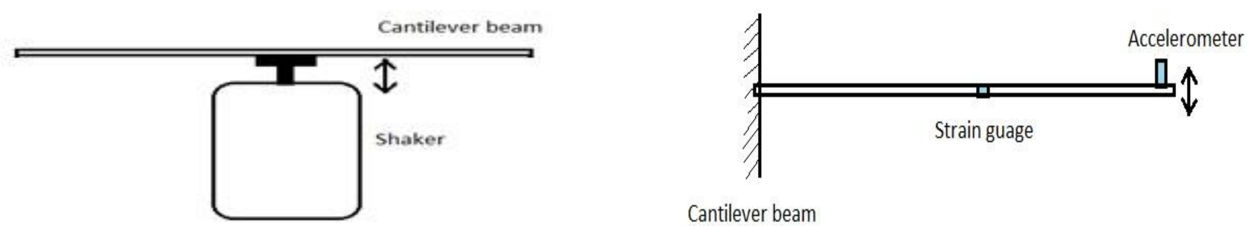


Fig 3.1: Configuration of the specimen

Experimental setup

The schematics of the experimental setup used for the demonstration of forced vibrations and natural vibrations are shown in Fig 3.2(a), Fig 3.2(b) respectively.



(a) Forced vibration **(b) Natural vibration**

Fig 2.2: Schematic of the experimental setups

Procedure

Part (A): Forced vibrations in the free-free beam – Demonstration experiment

i) Mount the beam on electrodynamic shaker.
ii) Define force amplitude by turning the knob. Make sure not to give very large amplitude which would overheat the device.
iii) Gradually increase forcing frequency and observe the change in the amplitude of vibrations.

iv) When the forcing frequency matches with one of the natural frequencies, resonance will be visually apparent (as shown in Fig 3.3).

v) Switch off the lights and start stroboscope. Adjust the flickering light frequency such that the beam appears stationary.

vi) Perform minor adjustments on the Stroboscope and forcing frequencies to attain maximum amplitude. Note down this fundamental frequency.

vii) Repeat the process for the first three fundamental frequencies and record the mode shapes for characterization. Representative second mode shape is shown in Fig 3.4.

Fig 3.3: High amplitude of vibrations at fundamental frequency

Fig 3.4: Second mode shape

Part (B): Analyze natural vibrations in a cantilever beam by using accelerometer data

i) Mount accelerometer at the end of the cantilever beam and connect it to data acquisition system.

ii) Provide initial end deflection to the beam and release the beam

iii) Once the vibration stabilizes (after a short initial interval) then begin recording the accelerometer and strain gauge data.

iv) Stop recording the data before the amplitudes diminish.

v) Perform FFT on the recorded data and get the free vibration characteristics.

Calculation and Results:

Perform theoretical analysis and compare your results with the experimental data. If there are no external driving forces and the beam is vibrating under the influence of gravitational forces, we get:

$$EI\frac{\partial^4 w}{\partial x^4} = -\mu\frac{\partial^2 w}{\partial t^2}$$

The above equation can be solved by variable separation to obtain:

$$\mathbf{W(x,t) = (C_1 \cos \beta x + C_2 \sin \beta x + C_3 \cosh \beta x + C_4 \sinh \beta x)(A \cos\omega t + B \sin\omega t)}$$

$$\boldsymbol{\beta^4} = \frac{\boldsymbol{\omega^2}}{\boldsymbol{(EI/\mu)}}$$

Where, μ is mass per unit length
E is the modulus of rigidity
I is moment of inertia
w is the displacement
x is the distance from fixed end
C1,C2,C3,C4 are constants of integration (to be determined by boundary conditions)

Free vibration of Cantilever Beam

Frequency	**Experimental**	**Theoretical**	**Error**
Fundamental (first harmonic)			
Second harmonic			
Third harmonic			
…			

As discussed in lab class, perform vibration analysis to assess natural frequency and damping characteristics of the following cantilever beams.

1. Aluminum beam of dimension: L = 1 m, b = 2.5 cm, h = 0.35 m,
   and elastic properties E = 69 GPa, Density = 2700 kg/m^3
   (Data included in zip file with roll number mapping)

2. Aluminum beam of dimension: L = 200 mm, b = 10 mm, h = 2 mm,
   and elastic properties E = 69 GPa, Mass = 11.27 gms
   Sandwich beam prepared with Al strips and metal particle filled polyurethane material of total dimension: L = 200 mm, b = 10 mm, h = 5.7 mm,
   and elastic properties E = 47.4 GPa, Mass = 27.75 gms
   (Mapped Roll numbers 1 to 25 use: Al_Beam_1.dat and Composite_Beam_1.dat
   Mapped Roll numbers 26 to 60 use: Al_Beam_2.dat and Composite_Beam_2.dat)